



© Universiti Tun Hussein Onn Malaysia Publisher's Office

**JSCDM**Journal homepage: <http://penerbit.uthm.edu.my/ojs/index.php/jscdm>  
e-ISSN : 2716-621XJournal of Soft  
Computing and  
Data Mining

# The Applications of Discrete Wavelet Transform in Image Processing: A Review

Adnan Mohsin Abdulazeez<sup>1</sup>, Diyar Qader Zeebaree<sup>2</sup>, Diloan Asaad Zebari<sup>3</sup>, Gheyath Mustafa Zebari<sup>4\*</sup>, Idrees Mohammed Najim Adeen<sup>5</sup>

<sup>1</sup>Presidency of Duhok Polytechnic University,  
Duhok, Kurdistan Region, IRAQ

<sup>2,3</sup>Research Center of Duhok Polytechnic University,  
Duhok, Kurdistan Region, IRAQ

<sup>4</sup>Computer Engineering Department,  
Cyprus International University, North Nicosia-Lefkoşa, North Cyprus, TURKEY

<sup>5</sup>Akre Technical College,  
Duhok Polytechnic University, Duhok, Kurdistan Region, IRAQ

\*Corresponding Author

DOI: <https://doi.org/10.30880/jscdm.2020.01.02.004>

Received 01 October 2020; Accepted 04 November 2020; Available online 15 December 2020

**Abstract:** Wavelet transform (WT) for image processing is one of the most popular methods in the frequency domain, the information of images could be represented as a group based on this method. The aim of this paper is to provide a wide-ranging review of the survey found able on wavelet-based image processing applications approaches. This paper reviews the newly published works on applying waves to image processing depending on the analysis of multiple solutions. the wavelet transformation reviewed in detail including wavelet function, integrated wavelet transformation, discrete wavelet transformation, rapid wavelet transformation, DWT properties, and DWT advantages. After reviewing the basics of wavelet transformation theory, various applications of wavelet are reviewed and multi-solution analysis, including image compression, image reduction, image optimization, and image watermark. In addition, we present the concept and theory of quadruple waves for the future progress of wavelet transform applications and quadruple solubility applications. The main contribution of this paper will be beneficial for scholars to execute effective image processing applications approaches.

**Keywords:** Wavelets, wavelet transform, multiresolution analysis, quaternion wavelets, image processing

## 1. Introduction

Nowadays, internet communication becomes a major part of the infrastructure. Based on the internet most of the applications of infrastructure systems can be operated [1]. The wavelet word was first presented by Grossman and Morlett [2], [3] in the early 1980s. They utilized the French term omelette, denotation to small wave. Wavelets have recently become a popular topic of dialogue in many scientific and engineering societies. Some waves see a new basis

for job representation; some consider them a technique for time-frequency analysis, and others consider them a new subject in mathematics. All of them are justified, given that a wavelet is a versatile tool with rich athletic content and great application potential. Wavelets have as of now been known as a solid unused numerical apparatus in the flag and picture treatment, time arrangement examination, geophysics, adjusting hypothesis, and most other areas.

To begin with, of all, waves were displayed into seismology to offer a time estimation to seismic spectroscopy where Fourier examination fizzled. The examination is perfect for considering steady information (information whose factual characteristics are steady over time), but it isn't very suitable for looking at information with measurably unforeseeable activities from past information. Since wavelet hypothesis has been concocted with such shaky information in intellect, its authenticity and solid comes about have gotten to be valuable in a number of precisions. Wavelet transformation is maybe the many exciting enhancement in the decade [4], as researchers fetched together many different areas, for example, signal processing, quantum mechanics, image processing, communications, computer knowledge, and mathematics [5].

Currently, wavelet is not the workspace for computer imaging and animation, but, for example, it is also utilized by the FBI to encrypt its database of one million fingerprints. In the future, experts may use wavelet examination to diagnose breast cancer, look for the cardiac anomaly, and weather forecast; for information compression, homogeneity, and image comprising; to verify fingerprints, DNA analysis, protein examination in addition to blood pressure, heart rate, and ECG examination. Also, in finance, descriptions of internet traffic, speech recognition, computer graphics, and many other areas. Wavelet examination offers extra freedom, compared to Fourier examination, because the selecting of atoms in the conversion was obtained from the wavelet is left to the user [6]. In this review, the concepts of wavelet theory are summarized in Section 2 with respect to image processing prospects. In Section 3, previous research in the field of wavelet applications in image processing is summarized, In Section 4, a new developing area of wavelets called quaternion wavelets, is discussed in detail. Finally, conclusions are reached, and future areas are suggested in Section 5.

## 2. Wavelet Transform

Wavelet Converter could be a scientific device for progressive picture investigation. It is valuable for preparing unsteady signals. The transformation depends on little waves, called wavelet, of changing recurrence and length. The wavelet change gives both the recurrence and the spatial portrayal of a picture [7]. Not at all like conventional Fourier change, time data is protected in this change. Wavelets are made with interpretations and extensions of a settled work called mother wavelets. This area analyzes the appropriateness of a wavelet change for the watermark of pictures and gives focal points of employing a wavelet change versus other changes [8], [9].

### 2.1 Wavelet Function

Wavelet function [10] The wavelet function is a type of measurement function that meets the four MRA requirements as a mathematical framework called multitasking analysis of measurement functions. The wavelength function is similar to the expression of the measurement function. Both integer translation and binary scaling are combined.

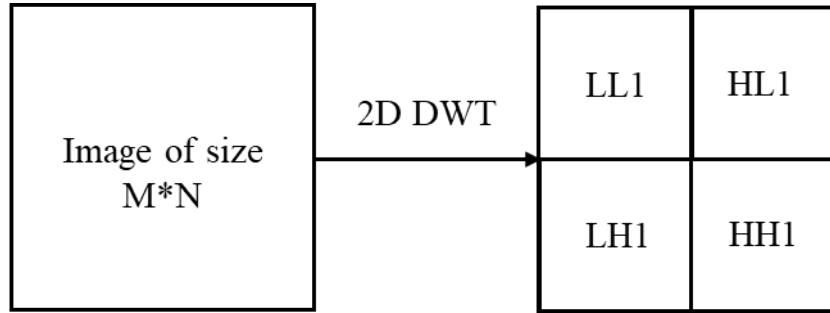
### 2.2 The Discrete Wavelet Transform (DWT)

DWT is a mathematical tool for pyramidal image decomposition. The transformation depends on a signal analysis into small waves or waves, of varying frequency and limited duration. Wavelet properties. The original reference to wavelet transformation parameters that contain location information is degraded. The original signal can be completely reconstructed by performing a reverse wavelet transformation on these coefficients [11].

DWT analyzes a picture into sub-images or sub-ranges [1, 12], three points of interest and one zoom. The groups are LL, LH, HL, and HH. Fig. 1 appears the sub-bands within the DWT. LL has moo frequencies within the level and vertical course. HH has tall frequencies in both the horizontal and vertical course. HL has tall frequencies within the level direction and moo frequencies within the vertical course. LH has moo frequencies within the even heading and tall frequencies within the vertical course. The low-frequency portion is made up of the unpleasant data of the signal whereas the high-frequency portion is made up of data approximately the edge components. The LL tape is the foremost vital tape since it contains most of the picture vitality and speaks to the picture guess. Watermarks can be included in high-frequency detail groups (LH, HL, and HH) since these ranges are less delicate to human vision. Counting these bars increments the strength of the watermark without any extra effect on the picture quality. At each level of decay, the primary DWT is executed within the vertical course, taken after by the DWT within the level course. The primary level of deterioration gives four sub-bands: LL1, LH1, HL1, and HH1. The LL sub-band from the past level is utilized as input for each sequential level of decay. This LL sub-band is partitioned into four multi-resolution sub-bands for the taking after coarse wavelength coefficients. This handle is rehashed a few times depending on the application for which it is utilized.

DWT highlights a fabulous spatial localization include that's broadly utilized to characterize picture zones where any unsettling influence can be covered up more effectively. Too, this procedure does not require the first picture to

identify the watermark. Hence, it is utilized in different applications related to signal to handle such as sound and video compression, clamour evacuation. The advanced photo watermark comprises of two forms that, to begin with incorporate the watermark with data and the moment extraction[13, 14].



**Fig. 1 - Sub-bands formed after 1-level DWT**

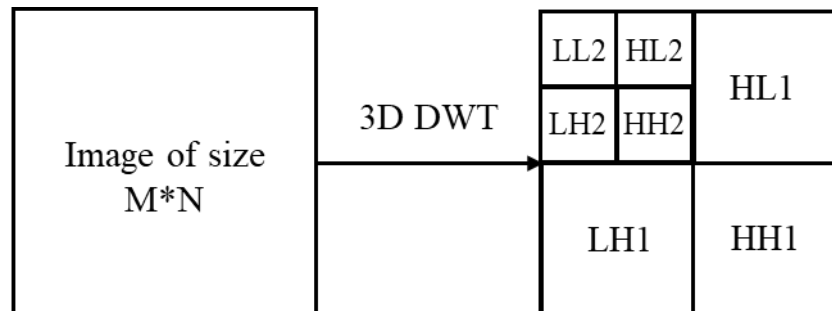
The reason why a separate wavelet transformation is better is a transformation of Fourier transform because DWT has a better ability to localize time and frequency. This makes image compression easier to hand[15].

### 2.3 Rapid Wavelet Transformation

An algorithm called Rapid Wavelet Transformation (FWT) [10, 16] has been developed by Mallat in order to achieve fast and efficient implementation of discrete wavelet transformation. FWT is similar to a two-domain sub-domain coding scheme that is also based on the relationship between DWT parameters in adjacent metrics.

### 2.4 Characteristics of DWT

The wavelet change breaks down the picture into three spatial bearings, i.e. flat, vertical and corner to corner. Consequently, wavelets reflect the anisotropic properties of HVS more accurately. Fig. 2 appears DWT deterioration of a picture utilizing three-level pyramid [8].



**Fig. 2 - DWT decomposition of an image using 3-level pyramid**

1. Wavelet Change is computationally effective and can be actualized by utilizing basic channel convolution.
2. With multi-resolution investigation, a picture can be spoken to at more than one determination level.
3. Size of DWT coefficients is bigger within the most reduced groups (LL) at each level of decay and is littler for other groups (HH, LH, HL).
4. The bigger the greatness of wavelet coefficient, the more critical it is.
5. Watermark discovery at lower resolutions is computationally successful since at each progressive determination level, less no. of recurrence groups is included.
6. Tall determination subgroups offer assistance to effortlessly find edge and surfaces designs in an image.

### 2.5 Advantages of DWT

The reasonableness of a wavelet change of a watermark of pictures may be considered due to the taking after reasons [8].

1. Wavelet change can plan HVS more accurately than other changes such as Change Fourier Change (DFT) or discrete cosine change (DCT) [10]. This permits higher vitality watermarks in zones where HVS is less touchy.

Counting a watermark in these zones permits the watermark to extend strength, without any noteworthy disintegration in picture quality.

2. The encoded image of the wavelet could be a multi-resolution portrayal of the picture. Thus, a picture can be shown at distinctive levels of determination and can be prepared consecutively from low to high resolution. The advantage of this strategy is that picture highlights which will not be identified with one exactness may be simple to find elsewhere.
3. The visual aesthetic impacts displayed by wavelet coded pictures are less clear compared to DCT since changing over wavelets does not break down the picture into squares of handling. At tall weight proportions, denied artefacts are recognizable in DCT compared to the pictures changed over to wavelets.
4. DWT and DCT could be a complete change system. Thus, any change within the conversion coefficients influences the whole picture unless DCT is executed employing a cluster-based approach. In any case, the DWT has the area of the spatial recurrence. This implies that it'll influence the picture locally, in the event that the watermark is included.
5. Another highlight is that the current JPEG 2000 picture compression standard is based on wavelet transformation.

### 3. Wavelet-Based Applications and Literature Review

As of late, wavelet change is progressively being utilized not as it were within the field of picture and signal preparing applications but too in numerous other distinctive areas, extending from arithmetic, material science and cosmology to measurements and financial matters. In image-processing applications, picture compression, picture decrease, and picture separation are at the cutting edge. Therefore, image processing is an ever-growing field, with novel applications being created at an expanding pace. It is an energizing and energizing locale to take part in nowadays, as the application regions extend from the amusement industry to the space program. One of the foremost curiously angles of this data transformation is the capacity to send and get complex information that goes past the plain composed content. Photo data, which is sent as computerized pictures, has become one of the most ways to Communication within the 21st century. Picture preparing may be a shape of flag preparing for which inputs are a picture; these can be photos or video outlines and picture handling yield as either a picture or a set of properties or parameters related to image processing [6]. most picture handling procedures involve treating the picture as a 2D flag and applying standard flag preparing procedures to it. In this area, we'll survey picture preparing, field by field, utilizing wavelet investigation methods.

#### 3.1 Image Compression

A wave may be a swaying work of time or space and a periodicity. In differentiate, waves are localized waves. Wavelet implies "little waves." Diminutiveness implies window work of a restricted length. Wavelets are capacities that meet particular scientific prerequisites and are utilized to speak to information or other functions. Wavelets are a waveform that includes a physically constrained length with a normal zero esteem. The wave itself shows a state that this work is oscillatory [17], [18]. Wavelets are scientific devices for various levelled decay capacities. Wavelet change has demonstrated to be a really valuable picture preparing apparatus in later a long time. It permits a work that can be portrayed in the unpleasant harsh frame, in expansion to points of interest that run from wide to limit. Wavelets are numerical capacities that offer assistance to portray the first image in a picture within the recurrence field, which can be separated into sub-images of diverse recurrence components. Each component is examined with a precision indistinguishable to its measure [19].

Wavelets are numerical capacities that cut information into diverse recurrence components, at that point consider each component with an exactness that matches its scale [20]. The essential thought behind wavelets is to scale concurring to scale. Wavelets are capacities that meet particular scientific necessities and are utilized to speak to information or other capacities. In wavelet examination, the scale we utilize to see at information plays an extraordinary part. Wavelength calculations prepare information with diverse measurements or resolutions. On the off chance that we see at a signal with an expansive "window", we'll take note generally highlights. Moreover, in case we see at a signal with a little "window", we'll notice little highlights. There are numerous individuals of the wavelet family, some of them, for the most part, found more supportive, agreeing to the taking after The wavelet corona is one of the most seasoned and least complex wavelets. Subsequently, any dialogue of waves starts with Haar wavelet. Daubechies wavelets are the foremost well-known wavelets. It speaks to the establishments of wavelet signal preparing and is utilized in numerous applications. This wavy is irregular and is comparable to a step work. Coiflets - The wavelet work contains  $2N$  minutes rise to and the scaling work has  $2N-1$  minutes break even with to 0. The capacities bolster the  $6N-1$  length. The Symlets are approximately symmetrical waves [20]. The characteristics of my wavelet family are comparable. Meyer- The Meyer wavelength and measuring work Meyer is characterized within the recurrence space. Biorthogonal - this family of waves uncovered the straight stage characteristic, which is essential to recreate the picture and signal. Utilizing two waves, one for corruption (on the cleared outside) and the other for reproduction (on the proper side) rather than one and one, curiously properties are inferred. Daubechies compressively backed orthogonal waves and applications show within the DWT. Her family has nine individuals in it [21].

Image compression is amazingly critical for effective exchange and capacity of pictures. It has numerous applications in data hypothesis, connected consonant examination, and numerous other areas. The objective of picture compression is to diminish the measure of the picture by abusing repetition inside the information without decreasing picture quality. Diminishing the record measure permits more pictures to be put away in a certain sum of disk space or memory [22]. Common reiteration is spatial redundancy, worldly reiteration, pixel redundancy, psycho-visual redundancy and factual redundancy [23]. Image compression is divided into two main techniques: transformations (separate cosine transformation) (DCT), Joint Photographic Experts Group (JPEG), Fast Fourier Transform (FFT), and wavelets, and non-transforms (Pulse-code modulation [PCM], differential pulse code modulation [DPCM]). Image compression is the primary application of the wavelet transform in image operation. Wavelet compression algorithms provide best compression and quality than the classically used JPEG algorithm. Most authors have contributed to the field. Even multispectral images (from satellite imagery, for instance) can be compressed with a wavelet-based method with multi-wavelet bases, for instance [21]. Khashman and Dimililer [23] proposed a method for compressing an advanced picture utilizing neural systems and a Haar wavelet change, with the point being to create an ideal picture compression framework. The discrete wavelet change can be effectively utilized in image-coding applications since their information decrease capabilities. The premise of DWT can be composed of any work (wavelet) that fulfils the prerequisites of multiresolution examination [23]. Elamaram and Praveen portrayed the essential thought of compression and endeavoured to diminish the normal number of bits per pixel to enough speak to a picture. Fourier-based changes (e.g., DCT and DFT) are proficient at abusing the low-frequency nature of a picture [22].

The high-frequency coefficients are coarsely quantized, and consequently, a recreated picture has destitute quality at the edges. Gupta and Garg [24] created a few basic capacities to compute DCT and to compress pictures. Picture compression was examined utilizing 2D discrete cosine change. The first picture is changed in eight-by-eight pieces, at that point by means of reverse change in eight by eight squares to recreate the picture and the error image (the distinction between the first and remade picture). Chowdhury and Khatun [20] depicted an unused picture compression conspire with a pruning proposition based on discrete wavelet change. It gives adequate high-compression proportions with no calculable debasement of picture quality. Singh et al. [22] examined the behaviour of diverse sorts of wavelet capacities with distinctive sorts of the picture and proposed a fitting wavelet work that can perform ideal compression for any given sort of picture. The impacts of diverse wavelet capacities and compression proportions were evaluated. This examination was carried out by calculating the compression proportion (CR), cruel square blunder, bits per pixel (BPP) and PSNR for diverse wavelets [6].

Benabadji in their term paper. In their work, they have utilized discrete wavelet change for clamour expulsion to compress fawning pictures. Sahnoun and Benabadji proposed a strategy of picture compression based on prove hypothesis. They have utilized the k-nearest neighbour (k-NN) calculation for compression. They have moreover utilized a distinctive method for compression, based on Fourier change and Huffman coding. Memane and Ruikar utilized discrete wavelet change in their work. They have analyzed the execution of diverse wavelets for partisan picture compression. Susilo et al. depicted a strategy of picture compression of X-sat pictures. In their framework, they have utilized as it were hardware-based arrangements in this lossless compression procedure. Hacıhaliloglu and Kartal have utilized discrete cosine change for lossless picture compression [25].

### 3.2 Image Denoising

Image handling, covering a wide run of operations such as digitization, replicating, sending, seeing etc. Tragically, this treatment by and large corrupts the picture quality by covering numerous sorts of clamour. In this way, to reestablish the initial picture structure, undesirable included commotion must be deciphered and evacuated. In image handling, commotion expulsion is accomplished through the utilize of filter-based commotion decrease methods. A wavelet transforms assistances a large number of small factors and a small number of large factors. General denoising ways that employ the wavelet transform consist of the following stages.

- Compute the wavelet transform of the specified noisy signal.
- Change noisy wavelet factors according to the rule.
- Compute the converse wavelet transform by utilizing the modified factors.

The consequent writing survey talks about denoising utilizing wavelet changes in a wide assortment of scenarios, i.e. by employing a number of thresholding strategies for a wide assortment of test pictures [26]. Frequently the picture is harmed due to commotion when getting and moving it. Picture commotion diminishment is utilized to evacuate included clamour whereas protecting as much as conceivable the imperative signal highlights [22]. Wavelet change gives us one way to diminish the clamour within the picture. With its fabulous localization include, wavelet changes rapidly changed into a crucial signal and picture preparing device for an assortment of applications, counting commotion and weight lessening. Wavelength clamour decrease attempts to dispense with commotion within the signal whereas protecting signal characteristics, in any case of their recurrence substance. The wavelet threshold (to begin with proposed by Donohue [24]) could be a signal-estimating method that abuses the wavelet change capabilities to diminish the signal. Disposes of clamour by murdering exchanges that are of no significance for a few limits. Analysts have created different methods for selecting commotion decrease parameters and so distant there's no technique for determining the "most" excellent worldwide limit. Yansun et al[22] presented a viable wavelet change

space commotion filtration strategy. This channel keeps up edges and kills clamour. Clamour is specially evacuated from wavelet change information on a given scale by comparing the information on this scale by relating the information on this scale with those within the bigger scales. The features are characterized and held since they are unequivocally related over the extend within the wavelet change field. Clamour is decided and evacuated due to its destitute cross-band correlation within the wavelet change field. The highlights stay generally undistorted since they are well localized in space within the wavelet change field; subsequently, the edges stay sharp after sifting.

Choi and Baranuik [22] characterized Besov balls (a curved set of pictures whose Besov criteria are restricted by half-diameters) within the areas of numerous wavelets and anticipated their crossing point utilizing projection on a curved cluster calculation (POCS). It is comparative to a kind of wavelet withdrawal to diminish picture commotion. This calculation gave a surprising advancement over the routine wavelength withdrawal calculation, based on a single wavelength field, such as the strong edge within the field of single wavelets. Yoon and Vaidyanathan [24] presented the custom limit chart and appeared that it outflanked the delicate and strong conventional graphs. Hsung et al. [21] Progress the conventional wavelet strategy by applying multivariate shrinkage to numerous wavelet change coefficients. To begin with, a straightforward strategy of classifying orthogonal second-order pre-filter was utilized in arrange to apply numerous waves of higher frequencies (whereas keeping up a pre-orthogonal channel for any different). At that point the edge choices were considered employing a non-impartial Stein estimator (Beyond any doubt) for each accuracy point, given that the commotion structure was known. Numerical tests have appeared that multivariate shrinkage of higher polymorphism usually yields superior execution, which the proposed LSURE has essentially outflanked routine Beyond any doubt in diminishing multivariate withdrawal, particularly in tall polymorphism. Veena et al. Displayed a technique for picture diminishment based on a less square approach utilizing wavelet channels [22]. This work is an expansion of the one-dimensional signal diminishment strategy based on the slightest square (recommended by Selesnick) to decrease 2-dimensional picture denoising.

The SPN extraction arranges of the SCI prepare may be a modern noteworthy procedure [24]. After analyzing the impediment of the discrete wavelet change (DWT) based denoising, utilizing dual-tree complex wavelet change (DTCWT) [21], [23] to extricate the SPN from an image, which can get way better SPN quality within the zone around solid edges. Other than, we point out that the conventional per-iodized boundary extension is the source of the destitute quality of SPN alongside the picture border. Subsequently, symmetric boundary expansion is presented in SPN extraction, which can essentially progress the quality of SPN together with the picture border. Broad tests appear that the proposed strategy yields better SCI execution than state of the craftsmanship approaches, such as the DWT based strategy [8], BM3D [27], Anisotropic [28], and CAGIF [29]. In addition, the proposed strategy moreover comes to promising result within the application of picture altering localization.

### 3.3 Image Enhancement

Image optimization is one of the gauge issues in high-quality images from digital cameras and HDTV. Because image clarity is simply affected by weather, lighting, wrong exposure to the camera or aperture settings, high automatic range in a perspective, etc., these conditions lead to an image that may suffer from information loss [30]. Several technologies have been developed to recover information in an image. In this section, we provide a literature review of some image optimization techniques to optimize a colour image, such as contrast, enhanced graph versions and formulas, smooth filtering, retinex, single or multi-band retinex, and multi-band wavelet transformation. Because colour images provide richer data on visual perception of grey images [31], colour image enhancement plays an important role in digital image processing [32]. The main aim of image improvement is to obtain more accurate picture details and selecting useful data. Images appear darker or with low contrast under poor lighting conditions. These low contrast images need to be improved. Image enhancement primarily improves the ability to interpret or perceive data in images for person viewers, and provides best inputs to other automated image processing methods [32]. In the literature, there is the most image enhancement strategy that can improve a digital image without damaging it. In general, ways to improve an image can be divided into two classes.

1. Spatial domain methods, and
2. Frequency domain methods

In spatial space strategies, we specifically bargain with picture pixels [33]. The pixel values are controlled to realize the required upgrade. In recurrence space strategies, the picture is, to begin with exchanged into the recurrence space [34]. This implies that the Fourier change of the picture is computed, to begin with. All the improvement operations are performed on the Fourier change of the image, and after, that a reverse Fourier change is performed to induce the resultant picture. Since a few features in a picture are barely distinguishable by eye, we frequently change pictures some time recently show. Histogram equalization is one of the foremost well-known strategies for differentiating improvement. Such an approach is for the most part valuable for pictures with destitute escalated distribution [34]. Since edges play a principal part in picture understanding, one great way to upgrade the differentiate is to upgrade the edges [6].

Stanford College made an elucidation- and direction-invariant denoising calculation for both 2-D and 3-D pictures utilizing wavelets [35]. The denoising handle is essentially a flag extraction plan. The wavelet-based approach is exceptionally different from routine filtering approaches since of its nonlinear property. A commonplace wavelet-based denoising calculation has the taking after steps:

1. Perform a sensible wavelet alter of the uproarious information.
2. Perform sensitive thresholding of the wavelet coefficients where the restrain depends on the clamour fluctuation.
3. Coefficients gotten from step 2 are at that point padded with zeros to provide a system and the organize is improved to induce the flag estimation.

Cases have shown up that this approach covered the commotion effectively while keeping up highlights inside the special flag. Other afterwards work in wavelet-based picture advancement consolidate the work by Stoschek and Hegerl on denoising of electron tomographic entertainments [29], Laine et al. have utilized wavelets for separate update and incorporate extraction of computerized mammography [36]. Lu and Healy of Dartmouth College made another separate update method for helpful pictures utilizing a multiscale wavelet-based edge representation [37]. They utilized the edge revelation and classification properties of wavelet-type representations. Tests have been conducted on diverse imaging modalities. One particular symptomatic application is the taking after of heart divider thickness in the midst of the cardiac cycle [38]. Lee et al. [39] use wavelet transform to decompose a fingerprint image into several directional sub-images. Orientation features and coherence features within these regions are calculated to recognize the fingerprint.

### 3.4 Image Watermarking

watermarking risen within the mid-90s as a teach, among the wide extent of the multidisciplinary field of information covering up, as a technique of securing computerized Image from any robbery act. It comprises of implanting a watermark (a follow) inside an advanced picture sometime recently utilizing or distributing it. The effectiveness of a watermarking strategy lies for the most part in its capacity to satisfy three prerequisites: strength, security and intangibility [40].

The generalized watermark demonstrate comprises of two forms: the consideration and discovery of the watermark as appeared in Fig. 3 and Fig. 4. In the implanting handle, the watermark may be encoded within the cover picture employing a particular key. This key is utilized to encode the watermark as an extra level of assurance. The yields of the implanting handle, the watermarked picture, are at that point exchanged to the recipient. In the discovery prepare, moreover called the extraction prepare, the watermark is extricated from the attacked signal. Amid exchange in the event that the signal isn't adjusted, the watermark is still shown and can be extracted.

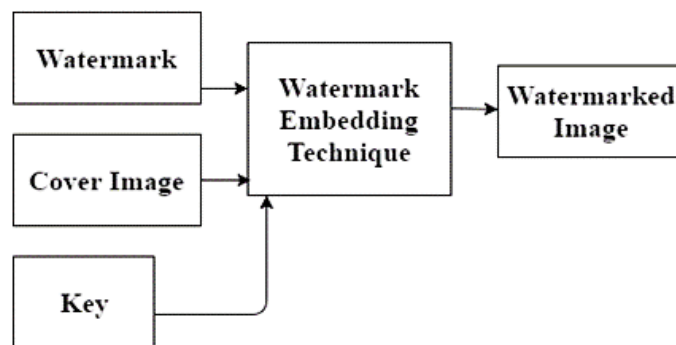


Fig. 3 - Watermark embedding

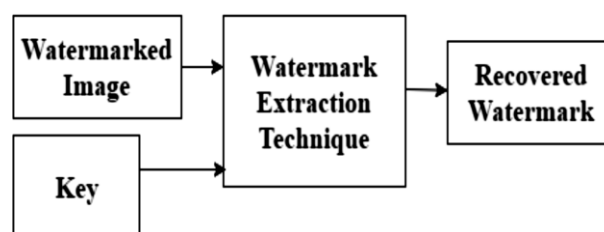


Fig. 4 - Recovered watermark

Hina Lala [11] Perform a two-dimensional DWT handle on the cover picture that analyzes the picture into four sub-bands: low-frequency estimation, high-frequency corner to corner, vertical flat low-frequency sub-bands. Moreover, 2D DWT is executed on the watermark picture that must be included within the cover picture. Here we utilized the wavelet radiance. The strategy utilized to enter a watermark is alpha mixing. The breaking down components of the cover picture and watermark are duplicated by a particular scaling calculate and included. Amid the implanting handle, the watermark measure must be littler than the cover picture, but the outline measure of both pictures must be break even with. The watermark included in this paper is evident or obvious in nature, so we joined it into the low-frequency close-up component of the cover picture.

M. Barney et al. [41] created a made strides watermark based on the wavelet by veiling pixels. Depends on covering up watermark concurring to HVS properties. The watermark is adaptively included to the greatest detail distinction. The watermark weight work is calculated as a straightforward item for the information extricated from the HVS show. Watermark identified by the interface. Victor et al. [42] created a calculation based on versatile watermarks in high-resolution sub-ranges of DWT. The weighting work may be an item expression of information extricated from the HVS show. Kayukamenirde and Crude [43] has created an adaptive wavelength watermark plot. Inserting is performed within the higher sub-ranges of wavelet change, in spite of the fact that this will clearly alter the picture determination. In arrange to maintain a strategic distance from the tactile weakening of the picture, watermark inclusion is carefully performed whereas utilizing HVS.

Chen and Shen [26] have created an unused effective calculation for delicate twofold watermarks utilizing a progressed pixel veiling show and a modern bit substitution based on a semi-fake irregular grouping. The strategy incorporates a solid and delicate watermark within the harsh portion and the touchy portion of the wavelet coefficients, making two watermarks non-overlapping [42], [44]. Peng Liu and Zhizhong Ding [45] recommended a watermark conspire for dazzle pictures based on an assessment of the measure of the wavelet tree. Watermark bits are included by comparing the huge distinction with the normal of the expansive distinction esteem and the most extreme contrast coefficients evaluated. Zhao Dawei et al. [46] He proposed a robust watermark calculation within the muddled field. It applies wavelet change locally and implants a watermark based on a chaotic calculated outline [47], [48].

The method by Jinshan Wang, Xiaodong Wang, Changjiang Zhang deliberate that in order to obtain the robust watermark, the watermark should be embedded in the low-frequency components of the image. First, the given image is scrambled using Arnold transform. Then logistic maps are used for scrambling. The original image is decomposed by a discrete wavelet transform. The watermarked image is mixed by Arnold transform. This watermarked image is embedded into the low-frequency coefficients of the discrete stationary wavelet domain and the final watermarked image is obtained. The final reconstructed image has good visual quality; thus, this method has good invisibility and good robustness to noise, rotation, and compression [49], [50].

#### 4. Quaternion Wavelet

As a numerical device, a wavelet change may be a primary breakthrough of Fourier change. It has great highlights of time recurrence and a few correctness's, and wavelet analysis hypothesis has gotten to be one of the foremost valuable devices for signal analysis, image handling, design acknowledgement and other areas. In picture preparing, the essential thought of wavelet change is to analyze a multi-solution picture. The initial picture is isolated into distinctive space and diverse recurrence sub-images, at that point the sub-image parameters are handled. Commonly utilized wavelet changes are genuine discrete wavelet changes, complex wavelet changes, etc. Genuine discrete wavelets and complex wavelet changes have two common drawbacks; to begin with, the little change of the genuine discrete wavelet change signal will create vitality to alter the conveyance of the wavelet coefficient; furthermore, the two-tree complex hinders, in spite of the fact that overcoming the primary issue, can create equivocality at the signal-phase at Two-Dimension picture highlight representation. While quad-wavelet change may be a modern instrument for handling multi-scale explanatory pictures, it is based on Hilbert's two-dimensional change hypothesis, which has an assessed steadiness of change and can overcome the above-mentioned abandons [51].

Quaternion wavelet change was made on the premise of quad-algebra, fourfold Fourier transform, and Hilbert change. Utilizing four changes of genuine discrete wavelets, the primary genuine discrete wavelet corresponds to the genuine fourfold fragment, and the other genuine discrete wavelet is gotten by the primary genuine discrete wavelet changes from.

Hilbert's wavelet change, which compares to the fanciful parts of the three-square, and the genuine four-wave wavelet Waves comprising of fourfold investigation signal. It can be caught on as an optimized genuine wavelet and advancement of complex wavelet, which has inexact consistency in change, copious stage data, restricted recurrence, etc. whereas keeping up the capacity to localize the time of the routine wavelet recurrence and channel plan utilizing Hilbert change a match of the two-fold tree structure, which Simple to realize [52], [53], [54], [55].



**Table 1 - Overview study of the existing research/surveys**

Author	Problems	Technics	Approach	Experiments Findings
Raghavendra et al. [22]	Efficient transmission and storage of images	Image compression is divided into two main techniques: 1. Transforms (Discrete Cosine Transform [DCT], Joint Photographic Experts Group [JPEG], Fast Fourier Transform [FFT], and wavelets), 2. Non-transforms (Pulse-code modulation [PCM], differential pulse code modulation [DPCM]).	Exploiting redundancy within the data without degrading the quality of the image.	The objective of image compression is to minimize the size of an image
Vyas and Paik [6]	Picture control incorporates a wide run of operations like digitizing, replicating, transmitting, showing ... etc. Shockingly, such controls, by and large, debase the picture quality by crossing numerous sorts of clamour.	A wavelet transforms assistances a large number of small factors and a small number of large factors.	Common denoising ways that utilize the wavelet change comprise of the taking after stages. • Compute the wavelet change of the required boisterous flag. • Change loud wavelet variables agreeing to the run the show. • Compute the banter wavelet change by utilizing the altered factors.	Noise evacuation is accomplished through the utilization of filtering-based denoising procedures.
Dolly and Raj [30]	Immaculateness of the picture is effectively impacted by climate, lighting, inaccurate camera exposures or opening settings, a tall auto-extend within the scene, etc., these conditions lead to a picture which will endure from the misfortune of information	Most methods have been enhanced to recover data in an image. like some of the image improvement methods for colour image improvement, such as contrast stretching, histogram Settlement and its improved versions, homomorphic filtration, retinex, single or Multiple domains retinex, and the wavelet multiscale transform.	Picture improvement strategies can broadly be separated into two categories: 1. Spatial space strategies, and 2. Recurrence space methods	The most reason for picture upgrade is to get more exact picture detail and centre valuable data.
Sharma [40]	Protecting digital images from any piracy act.	Implanting a watermark (a follow) inside an advanced picture sometime recently utilizing or distributing it.	A generalized watermarking show comprises of two forms: watermark implanting and location. In the implanting prepare, the watermark may be encoded into the cover picture employing a particular key. This key is utilized to scramble the watermark as an extra assurance level.	The proficiency of a watermarking strategy lies for the most part in its capacity to satisfy three prerequisites: strength, security and intangibility

---

			<p>The yield of the inserting prepares, the watermarked picture, is at that point transmitted to the beneficiary. In the discovery prepare moreover called extraction to prepare the watermark is extricated from the assaulted signal. Amid the transmission on the off chance that the signal is unmodified at that point the watermark is still shown and can be extracted.</p>	
Arfaoui et al. [51]	<p>The genuine discrete wavelet and the complex wavelet changes have two common drawbacks; to begin with, the genuine discrete wavelet change signal's little move will deliver the vitality of a wavelet coefficient dispersion alter; moment, dual-tree complex wavelets, in spite of the fact that they overcome the primary issue, can create signal stage equivocalness when two-dimensional picture highlights representation.</p>	<p>The quaternion wavelet change could be an unused multiscale investigation picture preparing device</p>	<p>it is based on the Hilbert two- dimensional alter speculation.</p>	<p>The quaternion wavelet change has evaluated move invariance and can well overcome these shortcomings said.</p>

---

## 5. Conclusion

This paper surveys the wavelet hypothesis, that a critical numerical instrument for signal and picture preparing, with an accentuation on its application to picture preparing. This paper affirms wavelet-based picture preparing applications which are commonly utilized nowadays and examinations different ways and approaches to wavelet-based picture preparing applications in detail. Moreover, it studies the applications and highlights of wavelet change. Most modern investigate subjects emerge in picture preparing for improving a procedure to fulfil two clashing prerequisites. Agent work was distinguished in picture compression, picture de-noising, picture watermarking, and picture advancement, examination, and classification. Compared to other instruments, such as the Fourier change, wavelet changes regularly give distant better; a much better; higher; a stronger; an improved" an improved spatial space localization property, basic to numerous picture applications. Wavelets have illustrated their significance in nearly all zones of signal preparing and picture processing. In numerous zones, methods based on wavelet changes speak to the leading of the accessible arrangements. Within the coming a long time, it is anticipated to see increasingly (effective) wavelet-based techniques within the field of picture preparing. it is anticipated picture reclamation consolidating wavelets, wavelet changes, and other measurable strategies to attain more prominent victory. Hypothetical investigate motivated by wavelets has driven to modern procedures, such as quaternion wavelets and quaternion changes that are more auspicious in sure conditions. Surveys of these modern wildernesses are probable to bring us more fruitful applications in image de-noising, picture enhancement, picture recouping.

## Acknowledgement

This research project has been sponsored by Presidency of Duhok Polytechnic University, Duhok, Kurdistan Region, IRAQ.

## References

- [1] Zeebaree, D. Q., Haron, H., Abdulazeez, A. M., & Zebari, D. A. (2019, April). Machine learning and Region Growing for Breast Cancer Segmentation. In 2019 International Conference on Advanced Science and Engineering (ICOASE) (pp. 88-93). IEEE.
- [2] Hariharan G. (2019). Wavelet Analysis—An Overview, in Wavelet Solutions for Reaction–Diffusion Problems in Science and Engineering: Springer, pp. 15-31.
- [3] Brifcani A. M. A. and Al-Bamerny J. N. (2010). Image compression analysis using multistage vector quantization based on discrete wavelet transform. in 2010 International Conference on Methods and Models in Computer Science (ICM2CS-2010), pp. 46-53: IEEE.
- [4] Zhang D. (2019). Wavelet transform, in Fundamentals of Image Data Mining: Springer. pp. 35-44.
- [5] Kumar R. and Saini B. (2012). Improved image denoising technique using neighboring wavelet coefficients of optimal wavelet with adaptive thresholding. International Journal of Computer Theory and Engineering. vol. 4, no. 3, p. 395.
- [6] Vyas A. and Paik J. (2016). Review of the Application of Wavelet Theory to Image Processing. IEIE Transactions on Smart Processing and Computing, vol. 5, no. 6, pp. 403-417.
- [7] Muthukrishnan, A. Kumar, D. V. and Kanagaraj M. (2019). Internet of image things-discrete wavelet transform and Gabor wavelet transform based image enhancement resolution technique for IoT satellite applications. Cognitive Systems Research, vol. 57, pp. 46-53.
- [8] Zebari, D. A., Zeebaree, D. Q., Saeed, J. N., Zebari, N. A., & Adel, A. Z. (2020). Image Steganography Based on Swarm Intelligence Algorithms: A Survey. people, 7(8), 9..
- [9] Waysi D. W. and Brifcani A. M. (2017). Enhanced Image Coding Scheme Based on Modified Embedded Zerotree Wavelet Transform (DMEZW). Science Journal of University of Zakho, vol. 5, no. 4, pp. 324-329.
- [10] Gonzalez, R. C., & Woods, R. E. (2002). Digital image processing.
- [11] Lala H. (2017). Digital image watermarking using discrete wavelet transform. International Research Journal of Engineering and Technology (IRJET), vol. 4, no. 01.
- [12] Alickovic, E. Kevric, J. and Subasi A. (2018). Performance evaluation of empirical mode decomposition, discrete wavelet transform, and wavelet packed decomposition for automated epileptic seizure detection and prediction. Biomedical signal processing and control, vol. 39, pp. 94-102.
- [13] Reichardt K. and Timm L. C. (2020). Spatial and Temporal Variability of SPAS Attributes: Analysis of Spatial and Temporal Series in Soil. Plant and Atmosphere: Springer, pp. 367-422.
- [14] Zamani, M. K. M., Musirin, I., Hassan, H., Shaaya, S. A., Sulaiman, S. I., Ghani, N. A. M., & Suliman, S. I. (2018). Active and reactive power scheduling optimization using firefly algorithm to improve voltage stability under load demand variation. *Indonesian Journal of Electrical Engineering and Computer Science*, 9(2), 365-372.
- [15] Abdulqader, D. M., Abdulazeez, A. M., & Zeebaree, D. Q. (2020). Machine Learning Supervised Algorithms of Gene Selection: A Review. Machine Learning, 62(03).
- [16] Brifcani A. M. A. and Brifcani W. M. A. (2010). Stego-based-crypto technique for high security applications. International Journal of Computer Theory and Engineering, vol. 2, no. 6, p. 835.
- [17] Jindal P. and Kaur R. B. (2016). Lossless image compression for storage reduction using pollination based optimization. in 2016 International Conference on Communication and Electronics Systems (ICCES), pp. 1-6: IEEE.
- [18] Zebari, D. A. Haron, H. Zeebaree, D. Q. and Zain A. M. (2019). A Simultaneous Approach for Compression and Encryption Techniques Using Deoxyribonucleic Acid. in 2019 13th International Conference on Software, Knowledge, Information Management and Applications (SKIMA), pp. 1-6: IEEE.
- [19] Singh, A. K. Tiwari, S. and Shukla V. (2012). Wavelet based multi class image classification using neural network. International Journal of Computer Applications, vol. 37, no. 4, pp. 21-25.
- [20] Seetharaman K. (2019). Applications of Image Compression on Agricultural Image Data Analysis. in Applications of Image Processing and Soft Computing Systems in Agriculture: IGI Global, pp. 208-241.
- [21] Boudiaf, A., Boubendira, K., Harrar, K., Saadoune, A., Ghodbane, H., Dahane, A., & Messai, O. (2019). Image compression of surface defects of the hot-rolled steel strip using Principal Component Analysis. *Matériaux & Techniques*, 107(2), 203.
- [22] Raghavendra, C. Sivasubramanian, S. and Kumaravel A. (2019). Improved image compression using effective lossless compression technique. Cluster Computing, vol. 22, no. 2, pp. 3911-3916.

- [23] Zeebaree, D. Q., Haron, H., Abdulazeez, A. M., & Zebari, D. A. (2019, April). Trainable Model Based on New Uniform LBP Feature to Identify the Risk of the Breast Cancer. In 2019 International Conference on Advanced Science and Engineering (ICOASE) (pp. 106-111). IEEE.
- [24] Taujuddin, N. Ibrahim, R. Sari, S. and Lashari S. A. (2018). Consolidating Literature for Images Compression and Its Techniques. Journal of Telecommunication, Electronic and Computer Engineering (JTEC), vol. 10, no. 1-5, pp. 35-39.
- [25] Patra, A. Bandyopadhyay, S. Chakraborty, D. and Saha A. (2020). A Novel Approach to Compression of Satellite Images Using Butterworth Filtering in Information. Photonics and Communication: Springer, pp. 179-183.
- [26] Barbhuiya A. and Hemachandran K. (2013). Wavelet tranformations & its major applications in digital image processing. International Journal of Engineering Research & Technology (IJERT), ISSN, pp. 2278-0181.
- [27] Mutlag, A.A., Khanapi Abd Ghani, M., Mohammed, M.A., Maashi, M.S., Mohd, O., Mostafa, S.A., Abdulkareem, K.H., Marques, G. and de la Torre Díez, I., 2020. MAFC: Multi-Agent Fog Computing Model for Healthcare Critical Tasks Management. Sensors, 20(7), p.1853.
- [28] Fracastoro, G. Thanou, D. and Frossard P. (2017). Graph-based transform coding with application to image compression. Institute of Electrical and Electronics Engineers.
- [29] Gupta M. and Garg A. K. (2012). Analysis of image compression algorithm using DCT. International Journal of Engineering Research and Applications (IJERA), vol. 2, no. 1, pp. 515-521.
- [30] Dolly B. and Raj D. (2018). Various Methods of Enhancement in Colored Images: A Review.
- [31] Sarala, N. Lavanya, M. and Lavanya M. (2017). A novel approach to multi modal hybrid image fusion using wavelet and contourlet transform for medical diagnosis applications. Imperial J. Interdisciplinary Res.(IJIR), vol. 3, no. 5, pp. 331-338.
- [32] Lee T.-H. H. (2017). Wavelet analysis for image processing. Institute of Communication Engineering, National Taiwan University, Taipei, Taiwan, ROC. On [http://disp.ee.ntu.edu.tw/henry/wavelet\\_analysis.pdf](http://disp.ee.ntu.edu.tw/henry/wavelet_analysis.pdf).
- [33] Ramiz M. and Quazi R. (2017). Hybrid technique for image enhancement. International Research Journal of Engineering and Technology (IRJET), vol. 4, no. 07.
- [34] Hanspal R. K. and Sahoo K. (2017). A Survey of Image Enhancement Techniques. International Journal of Science and Research (IJSR), vol. 6, no. 5, pp. 2467-2471.
- [35] Golilarz, N. A. Gao, H. Ali, W. and Shahid M. (2018). Hyper-spectral remote sensing image de-noising with three dimensional wavelet transform utilizing smooth nonlinear soft thresholding function, in 2018 15th International Computer Conference on Wavelet Active Media Technology and Information Processing (ICCWAMTIP), pp. 142-146: IEEE.
- [36] Chowdhury, M. "Mozammel Hoque, and Amina Khatun." (2012). Image compression using discrete wavelet transform. IJCSI International Journal of Computer Science, no. 9.4, pp. 327-330.
- [37] Singh P. T. and Manchanda P. (2014). Image Compression Using Wavelets. International Journal of Computer Science Issues (IJCSI), vol. 11, no. 4, p. 52.
- [38] Urooj S. and Singh S. P. (2017). Wavelet Transform-Based Soft Computational Techniques and Applications in Medical Imaging, in Biometrics: Concepts, Methodologies, Tools, and Applications: IGI Global. pp. 969-993.
- [39] Addison P. S. (2017). The illustrated wavelet transform handbook: introductory theory and applications in science, engineering, medicine and finance. CRC press.
- [40] Sharma A. (2015). Secure and Robust Watermarking Techniques for Medical Imaging.
- [41] Abdulkareem, K.H., Mohammed, M.A., Gunasekaran, S.S., Al-Mhiqani, M.N., Mutlag, A.A., Mostafa, S.A., Ali, N.S. and Ibrahim, D.A., 2019. A review of Fog computing and machine learning: Concepts, applications, challenges, and open issues. IEEE Access, 7, pp.153123-153140.
- [42] Lepski O. and Willer T. (2017). Estimation in the convolution structure density model. Part II: adaptation over the scale of anisotropic classes, arXiv preprint arXiv:1704.04420.
- [43] Jabade V. S. and Gengaje S. R. (2012). Logo based image copyright protection using discrete wavelet transform and fuzzy inference system. International Journal of Computer Applications, vol. 58, no. 10.
- [44] Mutlag, A.A., Abd Ghani, M.K., Arunkumar, N.A., Mohammed, M.A. and Mohd, O., 2019. Enabling technologies for fog computing in healthcare IoT systems. Future Generation Computer Systems, 90, pp.62-78..
- [45] Mostafa, S.A., Gunasekaran, S.S., Mustapha, A., Mohammed, M.A. and Abdullallah, W.M., 2019, July. Modelling an Adjustable Autonomous Multi-agent Internet of Things System for Elderly Smart Home. In International Conference on Applied Human Factors and Ergonomics (pp. 301-311). Springer, Cham.
- [46] Belkacem S. (2015, February). Chaos based image watermarking. Université de Batna.
- [47] Tang, Z. Wang, C. Chang, W. Li, C. Lu, Q. and Qu J. (2012). A combined noise-rejection method for UHF PD detection on-site. IEEE Transactions on Dielectrics and Electrical Insulation, vol. 19, no. 3, pp. 917-924.
- [48] Venkateswarlu, L., Rao, N. V., & Reddy, B. E. (2017, March). A Robust Double Watermarking Technique for Medical Images with Semi-fragility. In 2017 International Conference on Recent Advances in Electronics and Communication Technology (ICRAECT) (pp. 126-131). IEEE.
- [49] T. Tuncer and M. Kaya (2019). A novel image watermarking method based on center symmetric local binary pattern with minimum distortion. Optik, vol. 185, pp. 972-984.

- [50] Kumar S. and Indora S. (2016). Digital Image Watermarking Based on Wavelet Techniques: A Review.
- [51] Arfaoui, S., Mabrouk, A. B., & Cattani, C. (2020). New Type of Gegenbauer–Hermite Monogenic Polynomials and Associated Clifford Wavelets. *Journal of Mathematical Imaging and Vision*, 62(1), 73-97.
- [52] Yin, M., Liu, W., Shui, J., & Wu, J. (2012). Quaternion wavelet analysis and application in image denoising. *Mathematical Problems in Engineering*, 2012.
- [53] Zeebaree, D. Q., Haron, H., Abdulazeez, A. M., & Zeebaree, S. R. (2017). Combination of K-means clustering with Genetic Algorithm: A review. *International Journal of Applied Engineering Research*, 12(24), 14238-14245.
- [54] Zebari, R., Abdulazeez, A., Zeebaree, D., Zebari, D., & Saeed, J. (2020). A Comprehensive Review of Dimensionality Reduction Techniques for Feature Selection and Feature Extraction. *Journal of Applied Science and Technology Trends*, 1(2), 56-70.
- [55] Zeebaree, D. Q., Abdulazeez, A. M., Hassan, O. M. S., Zebari, D. A., & Saeed, J. N. (2020). Hiding Image by Using Contourlet Transform. In press.